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Capturing the wild - overview of wildlife capture methods, immobilizing agents and challenges involved to captures in general

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Abstract - Tiivistelmä - Referat

Wildlife capture is an event in which a wild animal is caught by a human. Reasons for wildlife captures vary: marking, collaring with a tracking device, disease surveillance, translocations related to conservation or commercial purposes, treating injuries and taking samples for research are some examples. Objective information about movement patterns and numbers of animals is needed for population management. Increased interest in disease monitoring and understanding the complex relationship between wildlife, people, domestic animals and environment has lead to a need for interdisciplinary approach to health issues, also known as 'One Health'. Gaining information from wildlife by capturing them has an important role in health research of all species.

Wildlife capture is often a complex event that should be carefully planned. Multiple non-chemical methods for capturing are available, such as traps, net-guns, drop-nets, drive nets or driving a group of animals into a corral. Chemical immobilization is usually done by remote delivery using a dart that injects immobilizing drugs to the animal. A large variety of drugs and drug combinations are used for wildlife captures. The animal species and previous research, equipment used and procedures that are supposed to be done during the capture are some of the main factors determining the type and length of anaesthesia needed, and therefore the specific drug combination preferred.

When talking about wildlife captures, two essential terms are usually involved: immobilisation and anaesthesia. Immobilized animal is uncapable to move or its movement is more or less restricted by physical restraint or immobilizing drugs. General anaesthesia is a drug-induced state characterized by anti-nociception, suppressed reflexes and loss of consciousness of the animal. Certain drugs can be used to create anxiolytic (calming), sedative (mental calming) or narcotic (opioid analgesics induced sedation) effects, and these may also create a smoother induction, maintenance or recovery from general anaesthesia.

There are multiple capture-related challenges and risks for both animals and humans involved. In the field unexpected events, such as sudden weather changes, injuries, failures of equipment, drug complications or accidental exposures, abrupt physiological reactions or getting infected by a pathogen from another species, can occur. Prevention is often easier that dealing with an accident or medical condition that has already happened.

This literature review aims to explain briefly why and how wildlife is captured, and gives a concise overview about some issues that need to be considered before a wildlife capture. In the end a short insight on Finnish large carnivore captures is presented with reflections to methods used in several other countries.

Avainsanat – Nyckelord – Keywords

wildlife capture, anaesthesia, immobilization, veterinary medicine, One Health, large carnivores, capture myopathy, emerging infectious diseases, conservation, wildlife

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"We are unique.
Chimpanzees are unique.
Dogs are unique.
But we humans are just not as different as we used to think."

- Jane Goodall –

"It surprises me how disinterested we are today about things
like physics, space, the universe and philosophy of our existence,
our purpose, our final destination.
It's a crazy world out there.
Be curious."

- Stephen Hawking –

" "X" never, ever marks the spot."

- Indiana Jones –

On the title page:
Upper photo: a giraffe in Kruger National Park
Lower photo: an elephant capture in Kruger National Park
Photos © Henna Kaarakainen

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1 INTRODUCTION – WHY IS WILDLIFE CAPTURED?

Figure 1. *African buffaloes (Syncerus caffer) in Kruger National park have been immobilized, captured and collared in association to bovine tuberculosis research projects (Oosthuizen et al. 2013). Photo © Henna Kaarakainen*

There are effective methods to study certain aspects of wildlife with indirect ways. For example faecal and hair samples can be used to determine some hormones and extract DNA (Macbeth et al. 2010, Morden et al. 2011, Granroth-Wilding et al. 2017). However, getting into straight physical contact with the wild animal is sometimes necessary, and according to Osofsky and Hirsch (2000) most common reasons for that are collaring with a tracking device and marking. GPS and VHF collars are used to track where the animals move (Osofsky & Hirsch 2000, Fahlman 2008, Kojola et al. 2009, Evans 2012). Animals are also translocated to other areas, for example, for species introduction and reintroduction, or when the genetic pool of the target area is narrow, or if the animals are causing trouble at the place where they are captured from (Kock et al. 2010, Lekolool 2012). Sometimes veterinarians may treat injuries or other medical conditions of a wild animal, especially with endangered species (Kock & Burroughs 2012).

In some countries ranching and private owning of wildlife is a big business. For example in South Africa the turnover from live sales at game auctions was estimated to be R4.328 billion (Taylor et al. 2015). These animals may be commercially translocated from one owner's ranch to another's or treated for injuries or disease. In fact, the huge scale of the private wildlife ownership in South Africa has created a whole, economically significant industry of wildlife capture and translocations since many drugs used in immobilization need to be handled by a veterinarian and captures themselves require special equipment and skilled, experienced personnel (Anderson 2003, Laubscher et al. 2015, Taylor et al. 2015).

Human-wildlife conflict is present in many parts of world between humans (*Homo sapiens sapiens*) and animals of various species (Dickman 2010). For example, in many African countries human-elephant conflict has taken forms in crop damage, destruction of infrastructure and injuries to both people and elephants (Dickman 2010). In many countries encounters with large carnivores result in challenges: lions (*Panthera leo*) cause livestock losses and economical damage in several African countries (Hemson 2003). In Fennoscandia (Finland, Norway and Sweden) problems are faced when protecting endangered grey wolf (*Canis lupus)* because of sheep, reindeer and dog kills, and mixed emotions that wolf raises among people (Linnell et al. 2003, Hiedanpää & Pellikka 2017). Increased growth of human populations, habitat fragmentation and availability of urban attractants, such as garbage and bird feeding places, lead to encounters between humans and black bears (*Ursus americanus*) in North America, which causes fear among people (Don Carlos et al. 2009).

Capturing and collaring the animals and tracking the animals give objective information about their movement patterns: for example, wolf critics in Finland claim that the wolves have begun to act fearlessly towards humans (Hiedanpää &

Pellikka 2017). Wolf critics even question the aims of the researchers at times and may accuse government authorities of being too strict with giving kill permits (Hiedanpää & Pellikka 2017). However, as Kojola et al. (2016) reported, the GPS data about the movements showed that wolves might learn to avoid moving close to residences when they become familiar with the area, even in areas where house density is higher. In light of these results, when wolf is spotted in close proximity of inhabited areas Kojola et al. (2016) suggest patience instead of an impetuous kill-decision. Thus, information gained from tracking can give objective tools, for example, to wildlife politics such as kill-permit regulation (Largecarnivores.fi 2019).

Legislative and political decicions should be based on objective findings rather than subjective feelings: the data that is gained from wildlife research and captures gives tools decicion making by identifying the possible challenges and their scope (Don Carlos et al. 2010). This can be seen especially important when the species under strong public and political pressure for culling is endangered or protected.

Wildlife can also be captured to get samples for disease studies and to determine physiological parameters of a specific species (Osofsky & Hirsch 2000, Cattet et al. 2008, Fahlman 2008, Chinnadurai et al. 2016). Monitoring wildlife diseases has started to play an increasing part in human medicine, too: the diseases of humans, wildlife and livestock are often shared, and understanding their close interaction by studying and monitoring the diseases helps in identifying, diagnosis, preventing and treating many diseases of both humans and non-human species (Worldbank 2010, Messenger et al. 2014, Nelson & Vincent 2015, Simpson et al. 2018). One example of such a disease infecting wildlife, humans and livestock is bovine tuberculosis (Figure 1).

Also other human health related aspects are involved in wildlife studies: for example, hibernation of ursids is physiologically a very challenging state, in which the bears gain a lot of stored fat, lie still for months and their blood cholesterol increases significantly (Evans et al. 2012). Despite of all these extreme changes, increased risks for vascular thrombosis or atherosclerosis is not reported in bears when they come out from their dens in springtime (Evans et al. 2012). Consequently, there is a large interest in studying hibernation and physiological factors enabling it, and possibly using ursids as a model for human cardiovascular diseases, obesity and space medicine (Laske et al. 2010).

2 REVIEW OF LITERATURE

2.1 HOW IS WILDLIFE CAPTURED?

2.1.1 Non-chemical methods

Foothold traps and foot snares are used for species that are difficult to approach: these have been used successfully when capturing for example large felids such as lynx (Kolbe et al. 2003) and lions (Frank et al. 2003, Laubscher et al. 2015). However, the foothold traps used in legal live captures are carefully and humanely designed equipment different from harsh wire snares used for illegal bush meat hunting (Laubscher et al. 2015). Cage traps are also used for many carnivores, and carcasses or pieces of meat are often used to lure the animal inside (Laubscher et al. 2015).

However, some olfactory attractants may be preferable compared to food baits to reduce the chance of accidental non-target species getting trapped: for example urine works as territorial odour (Laubscher et al. 2015). For some reason many wild felids are very attracted to the odour of Calvin Klein Obsession for Men parfyme, and it has been used in many large felid projects for trapping (Marker & Dickman 2003, Maffei et al. 2011, Riley et al. 2017). When foothold traps, foot snares or cage traps are used, it is essential to check the traps regularly and often, either by foot or using a camera: in cages animals can break their teeth or claws or get muscle injuries when attempting to escape (Cattet et al. 2003, Laubscher et al. 2005).

Drop-net capture is method used for relatively small species such as small sized antilopes or birds when trying to capture multiple individuals at the same time (Conner et al. 1987, Laubscher et al. 2005). Drop-net can be set using cables and poles, and the net with its attachments collapse either passively or manually when animals move underneath it (Jędrzejewski & Kamler 2004). After getting entangled the animals may be chemically tranquillized (Laubscher et al. 2005). The risk for injuries and stress-related physiological reactions is notable if drop-netting is poorly planned but the cost of personnel and vehicles is significantly lower compared to chemical immobilization from a helicopter (Laubscher et al. 2005).

Net gun can be used from a helicopter or from the ground, and based on the low mortality rates of the captured animals, net gunning is considered as a relatively safe technique especially in ungulates compared to other capture methods (Peterson et al. 2003, Webb et al. 2008). The device is held by a person who shoots a net at the animal (Laubscher et al. 2005). The escape time and distance are shorter compared to chemical immobilization by dart since the onset of the drug effect may take several minutes and during that time the animal is prone to get injured or overexcitated (Laubscher et al. 2005, Webb et al. 2008). Non-painful operations such as GPS collaring can sometimes be done without drugs but in more painful procedures, such as surgeries, chemical immobilization combined with proper anaesthesia and analgesia, is required after the animal is restrained with the net (Peterson et al. 2003). However, increased mortality was reported in deer capture cases when chemical immobilization following physical restraint is used compared to physical technique alone (Peterson et al. 2003).

In challenging environments, such as in very dense vegetation or urban areas, where darting or use of drop net is not practical, drive nets can be functional for some species (Peterson et al. 2003, Shury 2014). For example deer and some other ungulates have been successfully captured with them (Kock et al. 1987). Attention must be payed to the mesh size of the net and speed when driving animals towards the nets: the holes must be small enough to prevent animal getting entangled from it's legs or antlers, and driving the animals towards the net should be done slow enough to prevent abrasions and other injuries from the impact with the net (Peterson et al. 2003, Shury 2014).

Figure 2: *Semi-domestic reindeer (Rangifer tarandus tarandus) in the northern areas of Finland, Sweden and Norway live most of the year roaming wild in the forest. Twice a year they are gathered together for marking and taking some of the animals to be slaughtered. Some acute medical issues can also be treated at the same time, such as wounds or eye injuries. Reindeer round-ups are done by herding the animals non-chemically in huge corrals using snowmobiles, helicopters and people moving by foot. Photo © Henna Kaarakainen*

For mass captures driving animals actively or luring them passively into bomas or corrals are frequently used methods (Kock & Burroughs 2012, Laubscher 2015). For example, in South Africa plastic boma capture is very popular method for mass captures of many species, such as impala (*Aepyceros melampus*), kudu (*Tragelaphus strepsiceros*) and even some carnivores (Laubscher 2015, Sawicka et al. 2015). In Northern areas of Fennoscandia (Finland, Sweden and Norway) corrals made of wooden fences and tarps are used when semi-domesticated reindeer (*Rangifer tarandus tarandus*) are gathered twice a year for marking, antiparasitic medication and separating the animals to be slaughtered (Figure 2, Laaksonen et al. 2017). The animals can be herded to the desired direction by vehicles such as helicopters, snowmobiles and quad bikes or people moving on foot (Kock & Burroughs 2012, Laaksonen et al. 2017, Paliskuntain yhdistys 2019). Even though the equipment and personnel costs are high, this kind of methods can be cost-effective if large numbers of animals are captured, the procedure is well managed with sufficient number of well-trained people and proper vehicles (SANParks 2019). Since contact between individual animals and human is often small and immobilizing drugs are not needed, boma mass capture can cause less stress than darting or using physical methods where human contact with individual animals is required: this is advantage especially with stress-susceptiple species (Laubscher 2015, SANParks 2019).

2.1.2 Chemical methods

Chemical immobilization can be delivered as a remote injection, injection by close distance or oral ingestion. Oral drugs can be hid in baits: for example, alpha-chloralose that was experimentally used for very stress-susceptible Greater sandhill cranes (*Grus canadensis tabid*), and lower overall mortality and morbidity was reported when compared to most other capture techniques (Hartup et al. 2014).

Pole syringe is usually used when the drug is hand-injected but from a safe distance; this method is useful for example for animals in a trap or in a cage (Haigh et al. 1985). When the distance is short the drugs can be delivered by a blowpipe, which is practical roughly up to approximately 10 meters distance (Warren et al. 1979, Wenker 1997). For longer distances dart gun is often the best choice (Figure 3), and there are many options and manufacturers of various dart guns and darts (Kock and Burroughs 2012). Remote delivery projectors can be powered by compressed carbondioxide, or they can be powder load powered rifles (Isaza 2014). The darts are lightweight, two-chambered syringes powered by compressed gas in the back chamber, whereas the drug itself is placed in the anterior chamber (Isaza 2014). There is a tiny hole in the needle body covered by a plastic stopper which moves backwards when the dart hits the animal and allows the compressed air pressure to push the drug forward in the needle and to the muscle tissue of the animal (Isaza 2014). Also darts powered by black powder are available (Isaza 2014).

Darts dipped in paralyzing curare poison were used already by indigenous hunters in South America (Carl et al. 2014). These hunting poisons were prepared from several plants by traditional recipes, and they paralyzed the animal's locomotory and respiratory muscles by acting as potent neuromuscular blockers (Carl et al 2014). The first immobilizing agents used in scientific wildlife captures were also only paralyzing drugs: however, using them as sole immolizing agents is no longer ethically approvable, since they do not have analgesic, anxiolytic or anaesthetic effects (Osofsky & Hirsch 2000).

No immobilizing drug is perfect for all situations and for all animal species: choosing a drug, or usually a drug combination, depends on a variety of factors and is still under a lot of research (Kreeger et al. 2002). However, good immobilization cannot be defined only as incapability to move or the animal surviving from the procedure. As Fahlman (2008) noted, there is a lot between living and dying, and safe wildlife procedures should have minimal morbidity besides minimal mortality. Pain management is an essential part of proper anaesthesia (Greene 2001). Handling wild animals also creates a lot of physical and mental stress, which should be minimized by smooth loss of consciousness (Grimm et al. 2014, Chinnadurai et al. 2016).

An optimal immobilizing drug would have a short induction time. There is no drug which effect starts from the moment it hits the animal (Caulkett & Arnemo 2007b, Kock et al. 2014). During the time that the effects start to show and animal loses its capability to move it can escape a long way, hide and never be found or get injured or injure the people around (Caulkett & Arnemo 2007b, Kock et al. 2014). IThe drug should also have a wide safety margin since the dose is usually based on a very rough weight estimation, and on the other hand, the drug should preferably be safe to handle (Fahlman 2008, Kock et al. 2014). High potency means smaller volume of the chemical agent needed (Caulkett & Shury 2014). Most of the darts can carry only a volume of few milliliters, and also, the heavier the dart is, the more the weight affects to its flying route (Kock et al. 2014). Optimally the drug should also be stabile in various conditions: captures often happen in challenging weather and temperatures (Kock et al. 2014, Chinnadurai et al. 2016).

The drug should have minimal side effects for the animal, and it should be reversible in case of an emergency (Kreeger et al. 2002, Kock et al. 2014). It is also preferable to have an antagonist to finish the anaesthesia as soon as possible after the needed procedures are done to minimize the risks of the anaesthesia and surrounding environment for the animal (Kreeger et al. 2002, Kock et al. 2014).

Besides immobilization the need of analgesia should be considered: Chinnadurai et al. (2016) remind that as a rule of thumb that analgesics are needed in all procedures where the skin is penetrated by a tool which is larger than a basic hypodermic needle.

Figure 3a.

Figure 3b.

Figure 3a. *Remote immobilization of young blue wildebeest (Connochaetes taurinus) by darting on a privately owned game reserve.* ***Figure 3b*** *The animals were marked and blood samples were taken for routine health monitoring. Photos © Henna Kaarakainen*

2.1.3 Drugs used in wildlife anaesthesia and immobilization

As Lemke (2007) notes, classifying the drugs is a bit complicated due to the effects that may vary between species: for example, alpha-2 agonists create reliable sedation in dogs and cats but not in swines. Correspondingly, benzodiazepines have efficient sedative properties in swine, ferrets and rabbits but they do not work in the same manner in cats or younger dogs (Lemke 2007). However, one way to group some of the most common drugs that are used in immobilization and anaesthesia is presented in the following text.

Neuromuscular blockers

The first succesful chemical immobilization agents were neuromuscular blockers (Wenker 1997). These drugs paralyze the animal very quickly but have no effect to their conciousness (Martinez 2001). They can be antagonized with anticholinesterases such as neostigmine – but since neuromuscular blockers can cause severe bradycardia, anticholinergics such as atropine should be administered at the same time (Martinez 2001). There are many major problems with their usage: safety margin is very small, respiratory arrest due to paralyzed respiratory muscles and respiratory aspiration is reported to happen often, and mortality rate is high (Bergerud et al. 1964, Dugdale 2010). When they were used as only paralyzing agents without any anaesthesia, there were also ethical problems (Haigh 1982). Today, apart from some specific situations, neuromuscular blockers are mostly replaced by immobilizing drugs affecting the central nervous system (Wenker 1997, Kreeger et al. 2002).

There are two types of neuromuscular blockers (Clarke et al. 2013b):

1) Non-depolarizing agents that block neurotransmission (Clarke et al. 2013b). An example of these drugs is gallamine that has been used for crocodilian immobilization (Fleming 2014). They have also been reported to be useful in complementary drugs for short-term immobilization of chelonians during endotracheal intubation (Kaufman et al. 2003).

2) Depolarizing agents, for example succinylcholine, prevent re-polarization of neurons that is essential for an impulse transmission (Clarke et al. 2013b). Succinylcholine has been used in elephant and buffalo cullings (Pitts et al. 2002), crocodilian immobilizations (Fleming 2014) and a white rhinoceros (*Ceratotherium simum*) euthanasia (Pohlin et al. 2019). Daoust & Ortenburger (2001) suggested it as a part of humane chemical euthanasia for large stranded whales.

Opioids

Opioids belong to the most important immobilization drugs of wild herbivores but are also used in carnivores (Kreeger et al. 2002). Opioids bind to opioid receptors that are found in all the vertebrates, and they are also reversible with an antagonist (Lamont & Mathews 2007). The potency of lighter opioids can be a fraction of morphine's but on the other hand one of the most potent opioids, etorphine, which is a pure opioid receptor agonist, is 1000-1500 times as potent: with effective dosage of 10-20 µg/kg only 1.5-1.8 mL of a drug mixture with etorphine is enough to knock down an adult bull elephant, and such small volume of ultra potent opioid also fits easily in the dart (Kock & Burroughs 2012). Carphentanil is also a pure agonist with potency approximately 8000 times that of the morphine, and has longer duration of action than etorphine (Caulkett & Arnemo 2007b). Thiafentanyl is another opioid, approximately 6000 times as potent as morphine. It has wider therapeutic index compared to carphentanil, and has a more rapid onset, shorter duration and smaller risk of resedation after antagonist administration (Caulkett & Arnemo 2007b).

Cyclohexylamines

The cyclohexylamines are dissociative anaesthetics with a wide safety margin and relatively small negative effects to cardiovascular system (Caulkett & Arnemo 2007b). They are combined with other immobilizing drugs, usually with sedatives or tranquilizers such as xylazine or medetomidine since when used as sole agents they can cause convulsions, muscle rigidity and hyperthermia (Caulkett & Arnemo 2007b). Cyclohexylamines that have been commonly used in veterinary medicine are phencyclidine, ketamine and tiletamine (Dugdale 2010).

The most potent drug of this group, phencyclidine, was the first widely used cyclohexylamine in wildlife practice, especially in carnivores, but it had severe side effects such as convulsions, hallucinations and excitement (Beck 1972).

Ketamine is a short-acting cyclohexylamine that creates anaesthesia, immobility and amnesia by disrupting the functions of central nervous system (Grimm & Lamont 2014). In human use hallusinations are reported (Grimm & Lamont 2014). Because of ataxia in recoveries and muscular hypertonicity, ketamine is usually used in combinations with sedatives and tranquilizers, like other cyclohexylamines (Kock & Burroughs 2012). Also the large volume needed as a sole immobilizing agent is a limiting factor for example in large carnivore captures (Herbst et al. 1985).

Tiletamine is 2 to 3 times more pontet than ketamine (Beck 1972). Since as sole agent it frequently causes convulsions it is usually used as 1:1 mixture with zolazepam (Kock & Burroughs 2012). Tiletamine-zolazepam is widely used for example in large carnivore immobilization, and provides a smooth induction, good pain relief and muscle relaxation (Chinnadurai et al. 2016).

Alpha-2 adrenoceptor agonists

Alpha-2 adrenoceptor agonists are very commonly used drugs that sedate by depressing central nervous system (Lemke 2007). They create some level of analgesia, and act as muscle relaxants by binding to the alpha-2 adrenoceptors (Klein & Klide 1989; Wenker 1997). Alpha-2 receptors can be found in central nervous system, peripheral vascular beds, the gastrointestinal tract, multiple organs, platelets and sympathetic neuronal terminals (Tranquilli 2001). Although these drugs are dose-dependent, excitation may prevent or delay sedation or immobilization (Wenker 1997). Medetomidine, xylazine, detomidine and romifidine are examples of widely used alpha-2 agonists (Lemke 2007). To create general anaesthesia they are combined with other drugs (Chinnadurai et al. 2016).

One of the earliest reported alpha-2 –agonist combinations was five-to-one mixture of xylazine and ketamine, which was successfully used in many carnivores such as raccoons, bears, wolves and foxes (Wenker 1997). Ketamine provides a fast onset and works as the main anaesthetic drug while xylazine makes induction smoother and decreases the side effects of ketamine (Wenker 1997).

Detomidine was developed after xylazine and had two advantages when compared to xylazine: it tends to contract the uterus less and animals will more likely stand during the sedation (Clarke et al. 2013a). It can be combined with other agents like butorphanol (Grimm & Lamont 2014). This mixture with which a potent opioid etorphine is commonly used in wild equid anaesthesia (Walzer 2006).

Medetomidine is the most selective of the alpha-2 agonists (Klein & Klide 1989). Combination of ketamine and medetomidine is widely used for reliable immobilization and relaxation in many wild animal species (Clarke et al. 2013a). The pharmacology is similar to that of xylazine and it can also be combined with opioids (Kock & Burroughs 2012). However, as Murrel and Hellebrekers reviewed (2005) adverse effects, such as bradycardia, hypoxemia and hypertension, are reported in animals sedated with medetomidine. Also, cardiac output is often reduced following bradyarrhytmias and various conduction abnormalities (Murrel and Hellebrekers 2005).

Possibility to reverse the effects of these agents with alpha-2 antagonists is a great advantage and increases the safety for the animal (Chinnadurai et al. 2016). Commonly used antagonists are atipamezole, yohimbine and tolazoline (Grimm & Lamont 2014). The highest selectivity is provided by atipamezole whereas tolazoline is rather non-selective alpha-2 receptor antagonist (Klein & Klide 1989). However, when an alpha-2 antagonist is used for reversal of a mixture of drugs, it reverses only the alpha-2 agonist whereas effects of other drugs, for example cyclohexylamines, may still remain (Kock & Burroughs 2012).

There are some promising studies done with alpha-2 antagonist vatinoxan (previously called MK-467 and L-659,066), which has a very limited capability to pass the blood-brain barrier (Honkavaara et al. 2017, Restitutti et al. 2017, Adam et al. 2018, Tapio et al. 2018, Sainmaa et al. 2019). Therefore it alleviates the peripheral cardiopulmonary side effects of medetomidine in several domestic animal species (Honkavaara et al. 2017, Restitutti et al. 2017, Adam et al. 2018, Tapio et al. 2018), and captive markhors (*Capra falconeri*) (Sainmaa et al. 2019). In wildlife and zoo animal practice the large volume needed restricts vatinoxan's use in remote immobilization but with markhors it was succesfully administered intravenously promptly after animal was immobilized with medetomidine and ketamine by darting (Sainmaa et al. 2019). However, more studies are needed about the possible advantages of vatinoxan used with alpha-2 agonists.

Neuroleptics

Neuroleptics are used as tranquilizers for example in translocation and boma restraint situations to reduce stress and anxiety (Grimm & Lamont 2014). They can be divided into short-acting and long-acting neuroleptics (Grimm & Lamont 2014) ,which can be combined to get both a fast onset and a long-acting effect (Caulkett & Arnemo 2007b).

Short-acting neuroleptics

Butyrophenone derivatives and phenothiazine derivatives are dopamine antagonists that have minimal cardiovascular and respiratory side effect (Clarke et al. 2013a). They are classified as short-acting neuroleptics (Grimm & Lamont 2014). When used alone they may cause side effects such as hallusinations and aggression, which seems to be dose-dependent (Clarke et al. 2013a). In humans these effects are often not possible to see from outside but they are described by the patient afterwards (Clarke et al. 2013a). Since these effects are very subjective it cannot be told exactly whether animals feel the same way but regarding to otherwise same kind of physiological effects one can assume something similar to be experienced by animals (Clarke et al. 2013a).

Haloperidol is a butyrophenone derivative that cannot be mixed with opioids (Kock & Burroughs 2012). Effect lasts roughly up to some hours (Grimm & Lamont 2014). It is mainly used for post-capture transportation or boma restraint, and it can be combined with long-acting tranquillizers (Hofmeyr 1981, Kock & Burroughs 2012).

Azaperone is a butyrophenone tranquilizer that is used often in mixture to reduce the hypertensive effects of opioids following the vasoconstriction and increased cardiac output (Heard et al. 1992, Mentaberre et al. 2010, Van Zijll Langhout et al. 2016). In rhino and elephant captures it is commonly used in combination with etorphine and butorphanol (Buss et al. 2016).

Acepromazine (acetylpromazine) is the most potent phenothiazine derivative (Lemke 2007). Many phenothiazidine derivatives used in wildlife captures are long-acting and discussed in more detail in next subchapter: however, acepromazine is a short-acting neuroleptic effecting only few hours (Plumb 2008). It is usually combined with other drugs, for example an opioid or ketamine, to create anaesthesia and immobilization to wild animals (West et al. 2014). However, it has no analgesic effects (Lemke 2007).

Long-acting neuroleptics

Long acting neuroleptics (LANs) or long acting tranquillizers are dopamine receptor antagonists that have sedative, antipsychotic (mood-altering), strong antiemetic, tranquillizing and antihistaminic effects (Greene 2001). They are used to reduce stress during transportation, capture, introducing new animals into a group and in temporary restraint in enclosures (Wenker 1997). LANs reduce stress-related fasting, injuries and pathological physiological reactions that can in worst cases lead to severe illness or death (Wenker 1997). This makes LANs particularly valuable with the species that get very easily anxious from these kinds of events (Wenker 1997).

Zuclopenthixol acetate and perphenazine enthanate are the most commonly used long-acting neuroleptics (Grimm & Lamont 2014). Since they also block alpha-1 receptors, which are involved in blood pressure regulation, they reducearterial blood pressure by vasodilatation (Clarke et al. 2013a). They have also antiarrhytmic features (Greene 2001).

The onset of zuclopenthixol acetate takes a few hours after absoption from the muscle tissue and can last up to four days (Grimm & Lamont 2014). Effects of perphenazine enthanate start to show only after 24 hours referring to Kock & Burroughs (2012) or roughly after 12-16 hours referring to Grimm and Lamont (2014). The effects last for 7-10 days (Kock & Burroughs 2012).

Benzodiazepines

Benzodiazepines are sedatives that bind to the gamma-aminobutyric acid (GABA) receptors (Greene 2001). GABA is an inhibitory transmitter in the nervous system of mammals, and binding to the receptors results in hyperpolarization of nerve membranes by increasing the chloride conductance (Greene 2001). Benzodiazepines also block dopamine receptors and have a calming, antipsychotic and antiemetic effect (Clarke et al. 2013a). They also relax muscles, sedate and have anticonvulsant effects but they cannot provide anaesthesia when used alone in healthy animals (Clarke et al. 2013a). Anterogradic amnesia (memory loss) that benzodiazepines also provide may be useful when capturing same wild animals more than once (Kock & Burroughs 2012). The effects can be reversed with flumazenil (Greene 2001). Benzodiazepines can be administered if long-acting neuroleptics causes extrapyramidal side effects such as tremors, inappetence or abnormal breathing (Walzer et al. 2006).

Diazepam has little cardiovascular effects (Greene 2001). The anticonvulsant properties make it especially useful when given prior to or with ketamine (Clarke et al. 2013a). It has good muscle relaxing and anxiolytic properties (Kock & Burroughs 2012).

Midazolam is a short-acting sedative similar to diazepam but more potent (Greene 2001). Moreover, it has minimal cardiovascular effects, and good calming and muscle relaxing properties (Greene 2001). It has been succesfully used for example in rhino translocations as a tranquillizer, and also in carnivore captures orally in baits, which can reduce stress while the animal is restrained in the trap (Van Zijll Langhout et al. 2016).

Zolazepam is used in combination with tiletamine, a cyclohexylamine discussed already in more detail before (Greene 2001). It provides excellent potency with small injection volume, which makes this combination widely used in wild large carnivores and primates (Fowler & Miller 2003).

Other drugs

Hyaluronidase (or hyalase) liquifies hyaluronic acid of the soft tissue and makes immobilizing drugs to absorb faster (Kock & Burroughs 2014). It has been succesfully used, for example, in polar bears (*Ursus maritimus*) immobilized with a mixture of xylazine and zolazepam-tiletamine (Cattet & Obbard 2010) and in black rhino (*Diceros bicornis*) captures with etorphine and xylazine (Kock 1992).

Moreover, Kock (1992) notes that higher opioid doses combined to hyaluronidase use were associated with markedly faster induction, reduced muscle damage and lower body temperature.

Doxapram is a non-specific stimulant of central nervous system (Plumb 2008) used for acute apnoea in wildlife (Zeiler & Meyer 2017). However, it increases the oxygen need of brain and myocardial tissue which is why it is not recommended to patients already suffering from hypoxemia (Plumb 2008).

2.2 PREPARING FOR THE CAPTURE

Figure 4. *A rhino translocation requires a lot of people, special equipment and vehicles, careful planning and considering the safety issues for both people and animal. The rhino should be moved unharmed to the truck and translocation site, and people need to be aware of the movements of the rhino and possible other dangerous animals around. Photo © Henna Kaarakainen*

Captures are challenging situations that require a lot of planning in advance (Hernandez 2013). Well-planned and carefully executed immobilization improves safety of both animals and people (Arnemo et al. 2006, Caulkett & Shury 2014).

2.2.1 General considerations before the capture

Species specific charasteristics should be taken into consideration before capture: if the target animal is particularly prone to stress, it should be noted when choosing the method of capture (Arnemo et al. 2006). Stress relievement by using tranquilizers during capture or/and post-capture might decrease morbidity and mortality after capture (Wolfe & Miller 2016, Le Net et al. 2019).

Some species can be particularly dangerous to people (Caulkett & Shury 2014). With large carnivores or big-sized and aggressive herbivores such as African buffalo (*Syncerus caffer*) carrying a fire arm might be a necessary precaution (Hernandez 2013). People working with backup fire arms should be experienced to use them appropriately and safely (Caulkett & Shury 2014). Escape route for the people should be thought already before the capture event (Hernandez 2013). Eyes of the animal should be covered and ears plugged to minimize the external stimuli, and antlers or horns of the immobilized animal should be padded in case of sudden moves or arousal (Hernandez 2013).

The capture method to be used depends on multiple things, for example the animal species, number of animals to be captured, environment, weather, skills of the anaestetist and capture team, estimated duration of the immobilization, needed depth of the anaesthesia, vehicles and number of people that can be used (Caulkett & Arnemo 2007b, Chinnadurai et al. 2016). Chemical and physical capture methods are discussed more closely in their own chapter.

The permits required for wildlife studies and captures vary since all countries have their own legislation regarding to scientific uses of wildlife: being aware of the local regulations and compliance with them is crucial when planning a wildlife capture (Animal Care and Use Committee 1998).

Seamless team work and well-trained group, in which everybody knows their own task, is essential for a wildlife capture's success and safety (Arnemo et al. 2006, Kock & Burroughs 2012). In field unexpected events - such as sudden change in the weather, equipment failures or issue in safety of people or animals involved - might happen, and reacting to them fast enough is often possible only if they are already considered in advance (Caulkett & Shury 2014). In optimal situation everybody, or at least multiple people from the group, should be capable to react with anaesthetic complications such as unexpected recovery or too deep anaesthesia (Chinnadurai et al. 2016).

In wildlife capture exact weight of the animal is often not known so the dose of chemical immobilization agents has to be estimated (Wenker 1997). If the dose is under-estimated the drugs should be easily available for a top up administration or preferably they should be prepared already in advance. For example preparing a dart with very potent opioids in a moving vehicle is not safe for anybody (Hernandez 2013). If dose is overestimated or animal reacts undesirably to the anaesthetics, emergency drugs should be close or even already drawn to syringes for prompt reacting (Chinnadurai et al. 2016).

With large species that need to be transported special vehicles and personnel might be needed (Figure 4). Moreover, difficult terrain might cause special demands for vehicles used: for example, Nordic forest areas may be covered with deep snow and moving there may require snowmobiles or other vehicles designed for winter use (Helle & Jaakkola 2008).

Results from any data acquired from captures should be interpretted critically (Cattet et al. 2008, Morellet et al. 2009, Rainwater et al. 2013). Without radio tracking it is very hard to get exact information about animals' movements; however, when interpreting the data, it should be noted that the capture event itself can change behaviour and movement patterns even for several weeks (Morellet et al. 2009). On the other hand, Brivio et al. (2015) reported altered activity levels only immediately after capture of the ibex *(Capra ibex)*. They suggested their capture protocol (with reduced drug doses, approacting animals from ground and releasing them exactly to the same place where they were captured) caused less stress than the other protocols discussed in their article.

Certain blood variables, rectal temperature and many other physiological features may also be affected by capture event or drugs, and therefore the results may not always represent the true status of the animal in nature (Brivio et al. 2015, Cattet et al. 2018).

Faecal and hair samples are increasingly used non-invasive tools for genetic studies and determining cortisol levels (Macbeth et al. 2010, Andreassen et al. 2012, Van der Weyde et al. 2015). However, hair and faecal samples are not without their limitations either: for example, contamination of hair sample with saliva, urine, blood or faeces can affect the result (Macbeth et al. 2010, Heikkinen et al. 2018). DNA collected from faeces has to be of good quality (Heikkinen et al. 2018). However, Andreassen et al. (2012) noted that the markers they used for genetic studies in bears are highly species specific, and do not lead to false results even though DNA of other species would get mixed to the sample.

2.2.2 Monitoring the anaesthesia

Proper monitoring is crucial for animal's health but also for human safety, especially with dangerous wild animals (Chinnadurai et al. 2016). The scale of monitoring depends on resources available for capture project, number and education of people involved and field conditions in general.

Rectal temperature, respiratory auscultation, heart rate, possible murmurs and pulse quality are the most standard parameters evaluated during all anaesthetic procedures, and they can usually be monitored even in very basic field settings (Chinnadurai et al. 2016). Hypothermia is often seen in small animals, and hyperthermia is a common complication promptly after immobilization (Sawicka et al. 2014).

Figure 5. *A pulse oxymeter, used here in a chimpanzee anaesthesia, is a relatively cheap and informative device for basic anaesthesia monitoring. Photo © Henna Kaarakainen*

Wenker (1997) noted that besides a thermometer a portable pulse oximeter (Figure 5) should be included in minimal field monitoring equipment to monitor blood oxygen, by measuring the oxygen saturation of haemoglobin, and control oxygen administration. Potentional cuff sites are ears, tongue, paws and vulva (Heard 2014). In rabbits the base of the tails seems to be the best site (Heard 2014). According to Wenker (1997), additional oxygen should be supplied if blood oxygen saturation (SpO2) decreases below 90%.

Hydration status can be roughly determined by pinching a fold of skin gently, although this is not very accurate method: well-hydrated skin moves usually smoothly without a "sticky" feeling (Heard 2014). Eyes may sink, mucous membranes can feel dry and tear production might be decreased in dehydrated animals (Heard 2014).

Monitoring capillary refill time (CRT) is a method for evaluating the perfusion of peripheral tissues (Osofsky et al. 2000). A spot of gums is pressed until it turns pale and then released: CRT is the time the pressed spot takes to return to its normal color (Osofsky et al. 2000). Colour can indicate endotoxemia (hyperemia followed by pallor), anaemia (pallor) or hypoxemia (blueish colour) (Heard 2014).

Capnometry may be used for measuring the carbodioxide concentration in expired gases (Heard 2014). For accurate evaluation of acid-base status, blood gases and various haematologic variables blood gas analysis is used from an arterial blood sample (Fahlman 2008, Heard 2014). Arterial blood pressure measured indirectly by a cuff placed externally is relatively easy to monitor – however, indirect method is more inaccurate than direct blood pressure measured straight from the artery (Heard 2014). Nonetheless, direct method is not used that frequently in the field because it requires a catheter placed in artery (Heard 2014).

2.3 THE CHALLENGES AND RISKS FOR THE ANIMAL

There are always risks, leading to morbidity or mortality, involved in the capture process even though the aim is usually to pick only healthy and fit animals to be captured. Arnemo et al. (2006) divide capture-related deaths to 1) primary, capture event related risks (drowning during chase, dart injuries, direct physiological complications caused by the drugs) and 2) secondary, post-capture risks (stress, injuries from a tracking device, capture myopathy).

Field conditions in wild animal captures are often unpredictable and animal can hurt itself while escaping in difficult terrain (Zeiler & Meyer 2017). Misplaced darts can cause fractures and muscle injuries (Zeiler & Meyer 2017), or damage lungs and cause pneumothorax (Osofsky & Hirsch 2000). Predators or other dangerous animals around, such as lions, wolves, hippopotamuses, elephants or snakes (Zeiler & Meyer 2017), can create a threat both during and after the capture, especially for a drugged resedated animal (Walzer et al. 2006). For these reasons a proper knowledge of the predator situation and the terrain of the area should be gained prior the capture event (Chinnadurai et al. 2016, Zeiler & Meyer 2017). For example ditches, streams, cliffs, rocky areas and bogs may be potential risks both for the animal and the team. Joint dislocations and fractures in distal long bones are rather common injuries reported in impala captures (Zeiler & Meyer 2017). Limb and cervical fractures can happen when animals are chased in high speed (Caulkett & Shury 2014). Captures of male cervids and reindeer of both sexes should be avoided during the season when antlers grow in late spring-time: when antler grows rapidly, it is highly vascularized and possible damages can cause blood loss and pain (Caulkett & Shury 2014). The movements of the animal are often uncoordinated at the onset and end of the effect of immobilizing agents: for example Walzer et al. (2006) suggested fixing the head of wild equids down after giving an antagonist as long as the animal is properly awake and able to move its head safely.

Many felids and small carnivores are captured with a cage trap or box (Kolbe et al. 2003, Laubscher et al. 2015): however, claw and tooth injuries are reported (Laubscher et al. 2015). Wild felids captured with the help of trained hunting dogs often escape to trees where they are darted (Caulkett & Shury 2014). Arnemo et al. (2006) reported about a lynx that had to be euthanized due to falling from a tree after the darting and breaking a leg. Caulkett & Shury (2014) emphasize the importance carefully considered drug dosage and ambulatory or inflatable cushions prepared under the tree to avoid injuries. It is essential to monitor and check the trap often enough: for most species 1-2 times a day is needed (Caulkett & Shury 2014). Kolbe et al. (2003) did not recommend leghold traps and snares due to the injuries, such as foot freezing, they faced despite the carefully considered outside temperatures, short trap-check intervals and cushioned devices. Boulanger et al. (2008) reported that using snares in ursid capture had a connection to capture myopathy and significantly higher muscle enzyme levels in serum, indicating muscle damage, compared to remote chemical immobilization by dart or using barrel traps.

An optimal anaesthetic drug or drug combination plays a big role in succesfull capture, and often the safest options can only be found by trying various combinations and dosages: as Arnemo et al. (2006) reported, the mortality rate in bear captures reduced from 3.8% to 0.3% after medetomidine-tiletamine-zolazepam was taken as a standard immobilization combination for ursids, and etorphine was no longer used.

Hyperthermia is one of the most conspicuous adverse effect seen in wildlife captures and can lead to serious consequences (Sawicka et al. 2014) such as capture myopathy, which is discussed in more detail later. In some stress-susceptible species, such as impala (*Aepyceros melampus*), a capture event can result in severe hyperthermia regardless of whether the chemical agents are used for immobilization or not, and even though the animals would not been chased (Meyer et al. 2008). Furthermore, Fahlman et al. (2008) reported that 92 % of the wolverines (*Gulo gulo*) they caught using several methods suffered from hyperthermia.

Hyperthermia can pose a risk even in lower outside temperatures, following by excitation and stress-response to handling, chasing and/or transportation (Zeiler & Meyer 2017). Hyperthermia can also occur during anaesthesia (Ko & West 2014), and some drugs, such as ketamine, are associated with a higher risk for hyperthermia (Chinnadurai et al. 2016). Since cellular damage in essential organs, such as brain and kidneys, can occur in temperatures exceeding 41 °C, rectal temperature should be monitored during anaesthesia and possible hyperthermia stabilized (Thurmon et al. 1996). Cold water and ice can be administered topically, animal can be moved to a cooler place or low-temperature intravenous fluids can be used (Ko & West 2014). Sawicka et al. (2014) noticed, however, that intravenous saline and certain mist sprays were not as efficient coolers in hyperthermic blesbok (*Damaliscus pygargus phillipsi*) as water dousing and ice packs.

Hypothermia occurs often during anaesthesia, when animal’s normal thermoregulatory mechanisms are compromized by drugs (Kreeger et al. 2002). Getting wet and/or cold the environmental temperature, especially when the movement of the animal is restricted in traps, can predispose to decreased body temperature (Chinnadurai et al. 2016). Prevention is easier and more effective than attempts to correct already occurred hypothermia with towels or blankets in field conditions (Chinnadurai et al. 2016).

Cardiovascular changes, such as tachycardia and increased blood bressure can be amplified by certain immobilizing drugs. As Murrell & Hellebrekers (2005) rewieved, alpha-2 agonists cause peripheral vasoconstriction which may lead to hypertension. Bradycardia is commonly seen with medetomidine and may result in reduced cardiac output (Murrell & Hellebrekers 2005). Central nervous system depression is followed by decreased respiratory rate (Mich et al. 2008). Hypoxia is a risk in all wildlife captures and immobilizations, and therefore it should be prevented (Figure 6).

Capture itself causes stress in many ways for the animal: chasing, handling and transporting are always stressful situations (Chinnadurai et al. 2016). Also separation from the group causes anxiety and distress (Keeling and Gonyou 2001). All stress-causing factors should be avoided or at least kept as minimal as possible (Chinnadurai et al. 2016).

Figure 6. *Hypoxia is an anticipated complication during any wildlife anaesthesia (Fahlman 2008), and supplementary oxygen can be used in the field for preventing hypoxia. In this photo intranasal oxygen is delivered during a rhino immobilization. Photo © Henna Kaarakainen*

As Zeiler & Meyer (2017) note in their review about chemical capture of impala, adverse cardiovascular effects of capture drugs combined to animal's excitation, cathecolamine and glucocorticoid release in circulation followed by increased metabolism, oxygen demand and hypoxemia predispose to serious physiological complications, such as capture myopathy, cardiac arrest and death. Simple procedures, such as reducing the external stimuli, may decrease stress and risk of arousal (Figure 7).

With wildlife, reproductive status of the animal might be impossible to know before anaesthesia: however, captures should be avoided during seasons when females are known to be pregnant, give birth, lay eggs or foster the young (Chinnadurai et al. 2016).

The position of animal during anaesthesia should be considered carefully: for example better oxygenation has been noted in white and black rhinoceroses in sternal recumbency compared to lateral (Langhout et al. 2016). Ungulates in general are prone to ruminal bloat under anaesthesia, and therefore sternal body position is recommended (Wenker 1997). In case of acute bloat removing gas with gastrointestinal tube or even trocharizing the rumen externally from the left flank might be needed (Wenker 1997).

Capture related physical events after the actual capture event such as the radiocollar getting stuck to other body parts or environment, can cause injuries or death (Boulanger et al 2008). Resedation is possible several hours after capture event when using opioids as immobilizing agents, which exposes the animal to injuries and especially the herbivores and other prey animals to predators (Kreeger et al. 2002, Caulkett & Arnemo 2007a).

Figure 7. *Stress and excitement of this captive sabel (Hippotragus niger) are alleviated by blindfolding the animal and plugging the ears. The horns are also often padded. Photo © Henna Kaarakainen*

Cattet (2018) also emphasized that multiple captures of the same individual seem to be related to poor body condition when compared to the ones captured only once.

2.4 CAPTURE MYOPATHY

Capture myopathy (CM), also known as exertional rhabdomyolysis or exertional myopathy, is a multifactorial pathologic syndrome seen in free-ranging and captive wild animals in stressing situations such as captures, transportation and restraint (Paterson 2014). It can be manifested in many forms, and it can vary from relatively mild symptoms to severe complications and even death (Spraker 1993). CM is reported in various vertebrate species including, for example, terrestrial and marine mammals, birds, fish, amphibians and even lobsters (Paterson 2014).

Spraker (1993) described three main components of the pathogenesis of CM: fear, increased sympathetic system activity and muscle damage.

Processes maintaining normal electrochemical gradients in the muscle cells are highly dependable on the energy from ATP: sodium and calcium ions are pumped out from the muscle cells and potassium ions are taken into the cells (Petejova & Martinek 2014). As Spraker (1993) describes, fear and exhaustion can result in extreme activation of sympathetic nervous system characterized by extreme release of cathecolamines and corticosteroids. This can result in, for example, increased arterial pressure, increased cellular metabolism, hyperglycaemia, increased blood coagulation and glycogenolysis (Spraker 1993). Cathecolamines cause renal vasospasm which can increase the urea and creatinine concentrations in blood (Mentaberre et al. 2009). Elevated metabolic rate can cause depletion of ATP reserves from muscle cells, altered blood delivery, accumulation of lactic acid, hypoxaemia, decrease in nutrients and compromized removal of waste products from the cell (Paterson 2014). Ultimately, these reactions, often combined with intense muscular activity when escaping or struggling in physical restraint, are thought to result in muscular injury and necrosis (Blumstein et al. 2015). When muscle is injured, intracellular myoglobin is released, and it can cause acute kidney failure with its nephrotoxic and intratubular cast forming features (Petejova et al. 2014).

2.4.1 Types of capture myopathy syndromes

Spraker (1993) describes four different forms of CM: capture shock syndrome, ataxic myoglobinuric syndrome, ruptured muscle syndrome and delayed-peracute syndrome.

Capture shock syndrome

Capture shock syndrome has features of vasogenic-neurological shock following prolonged sympathetic stimulation (Spraker 1993). This leads to exhaustion of precapillaries which results in hypotension and reduced cardiac output, which can be followed by inadequate delivery of nutrients and oxygen to the tissues, intravascular coagulation and throbosis, decrease of pH and accumulation of cellular waste products (Spraker 1993). Increased heart and respiratory rate and hyperthermia can be seen, and death usually occurs in a few hours after capture (Paterson 2014).

Ataxic myoglobinuric syndrome

Ataxic myoglobinuric syndrome is the next phase following capture shock, often characterized by signs of myoglobinuria and mild or severe ataxia occurring within several hours or a few days (Paterson 2014). The toxic effects of myoglobin start to show; kidneys get hypoxic, mild or severe tubular necrosis can be seen, muscle lesions worsen, cellular swelling leads to disrupted cellular activity, and leakage of electrolytes and enzymes into blood cause kidney failure and azotemia in more severe cases (Spraker 1993). Potassium concentration and aspartate amino transferase (ASAT), lactate dehydrogenase (LDH) and creatine phosphokinase (CPK) activities are often increased, and mortality can be high in animals with significant symptoms (Paterson 2014).

Ruptured muscle syndrome

Usually ruptured muscle syndrome can be seen only after 1-2 days post-capture (Paterson 2014). The animal has survived from azotemia but muscle lesions have worsened. Large necrotic and haemorragic muscle areas can develop, and these muscles may rupture when try to bear weight (Spraker 1993); this may be seen, for example, as hyperflexion of the hock when gastrocnemius muscle is ruptured, but also other large muscles can get damaged (Paterson 2014).

Delayed-peracute syndrome

Animals with delayed-peracute syndrome have developed rhabdomyolysis with hyperkalemia and acidosis during a stressing situation but no clinical signs might be seen (Spraker 1993). If left unstressed, these animals may recover and never develope a more severe condition (Paterson 2014). However, when stressed again, such as captured another time or transported after capture, release of adrenaline and noradrenaline stimulates sympathetic activity in the body. Already developed latent hyperkalemia causes changes in electrical potential of cell membranes, and prevent cardiac and skeletal muscles from functioning normally, which can lead to ventricular fibrillation and cardiac arrest (Spraker 1993). The animal may try to escape but then suddenly stops or lies down, and dies within some minutes (Paterson 2014).

2.4.2 Prevention and treatment

Prevention is often much more efficient than treating CM (Ward et al. 2011). Choosing an optimal drug combination, minimizing the time and speed of chasing and restraint and other stressing factors can decrease stress in the animal (Brivio et al. 2015). Several treatments have been successfully used for treating CM. The condition can be very painful and thus proper analgesia should be considered among the first priorities (Paterson 2014). Although opioids are an efficient and relatively renal-safe option, also non-steroidal anti-inflammatories have been used in CM with no major renal damage reported (Paterson 2014). Drugs having anxiolytic and/or muscle relaxing properties have been used both as a part of treatment of CM and prevention (Smith et al. 2005, López-Olvera et al. 2006, Mentaberre et al. 2009, Ward et al. 2011). Corticosteroids, sodium bicarbonate, selenium, vitamin E and lactated Ringer's solution are recommended for treating CM (Businga et al. 2007). Physical therapy by gentle massage of the legs and releasing the weight from leg muscles with a sling support have also been reported to lead to succesful outcomes (Smith et al. 2005, Businga et al. 2007, Ward et al. 2011). Moreover, Smith et al. (2005) used haloperidol and Ward et al. (2011) midazolam to reduce the stress that physical therapy presumably for the animals caused.

2.4.3 Predisposing factors

Some animals seem to be more prone for CM than others. Interestingly, Bender (2015) noticed in his study that poor body condition was not connected to higher prevalence of CM in several ungulate species – actually, individuals in better body condition seemed to be in slightly higher risk of developing CM. When Blumstein et al. (2015) combined human and animal medicine with an evolutionary approach, species with highest maximal running speed and large brain mass seemed to be in significantly bigger risk for developing CM. They considered that animals running fast needed to develope a very potent sympatethic response burst for moving in high speed abruptly - and extreme release of cathecolamines is the key factor in the initiation of CM; an example of such species are ungulates (Figure 7). Moreover, life-historical factors in younger age can affect to the body's response in later life; therefore it could be speculated that extreme stress events in early age could perhaps predispose to severe CM or stress-related medical conditions in humans and wildlife (Blumstein et al. 2015).

Figure 7. *Any animal can develope capture myopathy but some animals, such as ungulates and long-legged birds, seem to be more prone to the syndrome (Blumstein et al. 2015). In the photo one example of an ungulate species, a group of Alpine ibex (Capra ibex). Photo © Henna Kaarakainen*

2.3.4 Transdiciplinary approach advantages: similarities to human medicine

In human medicine several etiologies, leading to the muscle injury followed by rhabdomyolysis, are described: Petejova & Martinek (2014) divide the etiologies to aquired (for example electrolyte imbalances, traumas, crush syndrome, toxications, malignant hyperthermia, extreme physical activity, ischemia) and hereditary (for example metabolic myopathies).

However, the etiological component that makes CM very special among other rhabdomyolysis forms is the strong emotion, such as fear and excitation, followed by extreme sympathetic activation as initiator of the muscle injury (Spraker 1993, Blumstein et al. 2015, Elikowski et al. 2018). Therefore, CM can occur as result from sole strong emotion, even without extreme muscle activation (Clark & Clark 2002).

This has made CM an interesting and promising model also to human medicine, as human and veterinary medicine professionals have noticed significant similarities between CM and emotional stress or grief induced heart symptoms in humans (Blumstein et al 2015, Elikowski et al. 2018).

2.5 RISKS FOR THE PEOPLE IN WILDLIFE CAPTURES

2.5.1 Physical risks for the people

Animal associated traumas such as bites, bruises or traumas from kicks, horns or antlers can happen (Hill et al. 1989). The dangerousness of a large carnivore is obvious but also small carnivores and many ungulates, especially in breeding season, can be very aggressive (Hernandez 2013). The animal being captured is not always the highest risk for the capture team but the other animals around have to be taken into consideration too: for example a pack of lions around or snakes on the ground have to be watched out (Caulkett & Shury 2014). Sometimes it is recommendable to name a person in the team to guard the rest of the team from the outside threats (Hernandez 2013).

Captures involve various vehicles and traffic accidents may also happen (Kock & Burroughs 2012, Caulkett & Shury 2014). Working around helicopter (Figure 8) even on the ground is risky, since people or equipment can end up to too close proximity with the vehicle's propels (Kock & Burroughs 2012, Caulkett & Shury 2014).

People are predisposed to other health risks in captures, too: for example extreme weather conditions can lead to sun burns or frost bites (Caulkett & Shury 2014). Heavy rainfalls can suddenly make roads not driveable, wind can push trees over cars or roads, and mist can make navigating tricky (Caulkett & Shury 2014). Moving in very difficult terrain, such as thick forest or rocky mountains, predispose to physical traumas and injuries (Caulkett & Shury 2014).

2.5.2 Chemical risks for the people

Chemical agents used in wildlife captures are often very potent in creating a smooth and rapid anaesthesia and immobilization for the animal in small volume that fits in the dart (Pourmand et al. 2017). Because the drugs are so potent they create a risk of exposure for the people (Hernandez 2013). Simple precautions, such as wearing gloves and safety glasses and having water available for diluting possible spills, reduce the risk of exposure to potent drugs (Caulkett & Arnemo 2007b).

When the capture involves particularly dangerous drugs, such as very potent opioids, emergency drugs and antagonists also for people should always be on hand in case of accidental self administration (Haymerle et al. 2010). These dangerous drugs should never be charged to dart and used alone by the vet (Caulkett & Shury 2014). The dart can still be partly pressurized or uncompletely emptied when taking the dart from the animal, and therefore pose a risk of drug spills to the veterinarian also after darting (Isaza 2014). The dart can also bounce back or be thrown at the darter by a primate (Isaza 2014). There should always be at least one person in the team who has access and knowledge to use the opioid antagonist: life-threatning effects such as loss of conciousness and respiratory symptoms might start even after one drop on the skin and as fast as within a few minutes (Haymerle et al. 2010).

Figure 8. *Unsteady conditions inside a helicopter can lead to accidents with darts or dart guns, and helicopter crashes can cause serious injuries and death (Kock & Burroughs 2012, Caulkett & Shury 2014). In this photo a succesfull rhino darting from a helicopter is happening. A skilled pilot drives the darted animal with the noise from the helicopter to the desired direction, close to the road and veterinary equipment.*

Photo © Henna Kaarakainen

Nalrexone is a pure antagonist registered for humans and suggested to be the drug of choice for accidental self administration of etorphine, carfentanil or thiafentanil (Haymerle et al. 2010). It is available as an injectable solution for animals and oral product registered for human use. Since in opioid accidents (of ultra-potent capture opioids) a rapid, potent and rather long-acting antagonist is needed, injectable naltrexone has been experimented in humans: Haymerle et al. (2010) discovered in their questionnaire that a facial exposure of carfentanil and xylazine mixture was succesfully reversed with 50 mg of naltrexone given intramuscularly.

A commercial etorphine product M99 (Novartis Animal Health) is delivered with an opiate antidote diprenorphine for animal use. The technical information suggests it also for human use in accidental self-administration, if naloxone is not available. However, as Haymerle et al. (2010) emphasize, diprenorhine has also agonistic qualities which can lead to respiratory depression and administering more diprenorphine to the patient – causing even more severe symptoms.

Naloxone and nalmefene are pure opioid antagonists registered for human use besides naltrexone (Barsan et al. 1989). The problem with naloxone is that it is more commonly used for overdoses of less potent opioids in humans, and it is available in only 1 mg/ml concentration at maximum - whereas up to 2 mg/kg is needed to antagonise ultrapotent opioids used in wildlife captures (Haymerle et al. 2010). Also the duration of naloxone is rather short with approximately 15 minutes compared to 14 times longer duration of nalmefene, and resedatyion afterwards has been reported (Barsan et al. 1989).

For some drugs, such as alpha-2 agonists, no antidote is registered for human use. Accidental self administration of xylazine has been reported to have caused loss of conciousness, hypotension, asystole, areflexia, apnoea and coma, thus it must be handled carefully (Haymerle et al. 2010). Furthermore, only 0.005 ml of highly concentrated medetomidine (40 mg/ml), used in wildlife captures, equals the intravenous dose reported to result in cardiac arrest in humans (Pourmand et al. 2017).

Atipamezole has been shown to reverse the effects of dexmedetomidine in ratio of 60:1 in one human study (Scheinin et al. 1998). However, Pourmand et al. (2017) noted that the alpha-2 agonist dose needed for deep sedation in humans is 10 times less compared to other species, including primates – yet humans seem to need 10 times larger dose atipamezole for reversal. They suggest an emergency protocol for human overdose from potent alpha-2 agonists 100 mg atipamezole intramuscularly should be considered when medical aid is not available.

2.6 INTERSPECIES PATHOGENS

Pathogens transmitted between wildlife and other subjects are a significant challenge in wildlife captures, especially in wildlife translocations (Kock et al. 2010). Several ways of pathogen transmission are reported, and understanding the complex relationship between human action, wildlife and domestic animals related to pathogens helps to prevent the disease related failures in wildlife captures (Kock et al. 2010).

2.6.1 From wildlife to human

Zoonoses are diseases that can be transmitted from animal host to a human. For example, over 60% of emerging infectious diseases in US are zoonoses, and 72% of them came from wildlife (Jones et al. 2008). Careful handling and protective clothing are recommended to prevent zoonotic disease transmission (Caulkett & Shury 2014). According to Hill et al. (1998) more than 30% of zoo veterinarians have been infected by a zoonosis, of which ringworm and psittacosis were the most common infections. The zoonotic disease risks depend, for example, on animal species and climate (Worldbank 2010). Required vaccinations should be up-to-date when working with wildlife species known to predispose to a specific disease, such as rabies prophylaxis in bat-related work (Caulkett & Shury 2014).

2.6.2 From human to wildlife

On the other hand, wildlife captures and handling of wildife in other situations involve a risk to transfer pathogens from humans to wildlife (Kock et al 2010, Messenger et al. 2014). To emphasize the threat for animals getting infected by humans these diseases are sometimes also called reverse zoonoses or anthroponoses (Messenger et al. 2014, Nelson & Vincent 2015). For example, Nelson & Vincent note in their review (2015) that swine as a source of influenza A virus infecting humans happens actually less frequently than transmissions from humans to pigs. *Mycobacterium tuberculosis*, protozoans *Cryptosporidium* and *Giardia* causing gastrointestinal infections and methicillin-resistent *Staphylococcus aureus* are other examples of pathogens reported to have infected animals by humans (Messenger et al. 2014).

2.6.3 From anthropogenic action to wildlife (and to human)

Hing et al. (2016) add an interesting aspect of stress to the picture of shared diseases between human and non-human species: it seems that physiological stress affects to individual animal's immunity and thus susceptibility to get infected with a disease, or start showing signs of already acquired disease. This can be followed by increased level of shedding infectious agents (Hing et al. 2016). In their article Hing et al. refer to studies suggesting that anthropogenic stressors such as bat culling operations, climate change and urbanisation might alter bats' immune reactions and therefore increase a possibility of, for example, hendra virus spillover from bats to humans. Outbreaks of hendra virus have caused fatalities in humans and horses (Hing et al. 2016). Moreover, translocations of wildlife can cause stress and activate latent infections: an example was a translocation of 57 Arabian oryx (*Oryx leucoryx)* in Saudi Arabia. Animals with no signs of disease, and conditioned to capture system, were relocated to a wildlife research centre (Kock et al. 2010). They died of tuberculosis after a few weeks, having been probably subclinically infected.

2.6.4 From wildlife to wildlife

Diseases transmitted between wild animals, for example in translocations, are a risk: Transported animals can bring pathogens to immunologically naïve animals of the relocation site, or the animals there can infect transported animals (Kock et al. 2010). Fatalities of immunologically naïve black rhinoceroses (*Diceros bicornis*) have occurred after conservation-related translocations to trypanosomosis infected areas (Kock et al. 1999). In 1930's muskrats *(Ondatra zibethicus)* were introduced into area of Soviet Union to strengthen the population hunted for fur (Kock et al. 2010). However, local water voles (*Arvicola amphibious*) carrying enzootic tularemia infected quickly the muskrats, causing a massive epizootic – and after that multiple muskrat trappers were infected too, since tularemia is a zoonosis (Kock et al. 2010).

2.6.5 From wildlife to domestic animals

Only a few zebras (*Equus burchelli)* brought from Namibia are suspected to have caused the catastrophical outbreak of African horse sickness in Spain in 1987, which resulted in numerous local horse fatalies (Mellor et al. 1990). Therefore, livestock, other domestic or semi-domestic animals around should be considered when pondering the risks related to wildlife captures or translocations following them (Worldbank 2010).

2.6.6 From domestic animals to wildlife

Kock et al. (2010) notes that bluetongue, tuberculosis and brucellosis are common infections transmissing from local horses and donkeys to translocated wild or semi-wild equids. Pathogens can spread from livestock to wildlife besides by direct contact, also by vector transmission (Bengis et al. 2004).

Translocations, which are one reason for numerous wildlife captures, may be essential for conservation or other issues: however, Kock et al. (2010) recommends certain precautions to minimize the disease risks, such as investigating well the disease history of translocated animals, testing and carefully interpreting results of them (especially tuberculin test), considering vaccinations in some cases and identifying profoundly the major disease concerns of the relocation site. All things considered, characteristics of interspecies pathogen risks are affected by very complex human-wildlife-livestock interface consisting of many factors, such as the level of human-activities, cultural elements, veterinary and human medicinary actions and resources, awareness and educating the local people (Simpson et al. 2018, Worldbank 2010).

2.7 A BRIEF INSIGHT TO LARGE CARNIVORE CAPTURES AND RESEARCH IN FINLAND

2.7.1 Large carnivores in Finland

There are four species of large carnivores in Finland; grey wolf (*Canis lupus*), brown bear (*Ursus arctos)*, wolverine (*Gulo gulo)* and European lynx (*Lynx lynx*). Grey wolf is classified as an endangered species (Kojola et al. 2016). The estimated population of wolves in March 2018 was 165-190 (Heikkinen et al. 2018).

Figure 9. *Bears (Ursus arctos) are not captured or collared for research at the moment in Finland (May 2019). In past, during 1998-2003 numerous bears were radio collared and their movements were tracked. During the captures bears were also weighed and ear tagged for identification. Photo © Henna Kaarakainen*

Wolverine is considered endangered species, and according to a decree of Ministry of Agriculture and Forestry (2019) the population in whole country was 270-300 during winter 2017/2018 due to the strenghtened population.

Lynx is the most numerous large carnivore in Finland. Number of lynx has grown since then: the population estimation in 2018 before hunting season was 1865-1990 individuals of over one year age (Holmala et al. 2018). The estimated population of bears in Finland in 2018 was 2020-2130 (Heikkinen et al. 2019).

2.7.2 Institutes and authorities involved in research in Finland

The large carnivore research in Finland is done by Natural Resources Institute Finland (Luke 2019). In addition to population management and number of animals, the research focus with large carnivores is in genetic variation, sex and age ratios, habitat use, movement patterns, behaviour, diet, and co-existence with humans and human-owned animals. The Finnish Wildlife Agency (Suomen Riistakeskus) works to promote sustainable game management and hunting activities (Finnish Wildlife Agency 2019). Ministry of Agriculture and Forestry is the highest authority supervising activities of Luke and The Finnish Wildlife Agency (Luke 2019). As a member of EU, Finland also has to follow EU guidelines in its policies and decisions (Luke 2019). The EU Habitats Directive aims to support biodiversity and regulates the status of large carnivores (Council directive 92/43/EEC).

2.7.3 The aims for large carnivore research and captures in Finland

In law the large carnivores in Finland are protected; however, according to Hunting Act (Section 41 a, amendment 159/2011) exceptional hunt and kill permits may be granted by the Finnish Wildlife Agency (Hunting Act 1993). A permit to kill might be granted, for example, for a carnivore individual that causes losses to agriculture, livestock farming or forestry, or is a safety threat for people (Hunting Act 1993). However, before an exceptional permit is granted for killing the conservational status, viability of population and requirements for exception must known and considered: if the population is not strong enough, or if alternative options for dealing with the situation are available (for example, translocating an individual living that comes too close to habitated areas) another way of management may be considered instead of hunting or kill permit. The same law determines the requirements for a capture of an individual animal in Finland regarding to, for example, research, conservation or translocation purposes (Hunting Act 1993, Largecarnivores.fi 2019). These decisions, however, are based on information that is gained from large carnivore research (Largegarnivores.fi 2019).

Large carnivores have been subjects of complex debates, and human-wildlife conflict is present in various forms regarding to all four species in Finland (Largecarnivores.fi 2019). People representing different interests have disagreements not only on current population sizes, but also complex social, cultural, political and ethical aspects are present (Hiedanpää & Pellikka 2017, Largecarnivores.fi 2019).

Significantly emotional debate in past decades has been sparked about the wolf because of dog attacks, reindeer and domestic animal losses and people's feeling of unsafety when wolves are known to move close to habitated areas (Hiedanpää & Pellikka 2017). Bears cause fear among the people and damages to bee yards, reindeer and domestic animals (Kojola et al. 2018, Largecarnivores.fi 2019). Lynx occasionally kill domestic animals (Largecarnivores.fi 2019). Wolverines are very few in numbers but cause heavy losses in reindeer herding areas, and thus negative effects of this species are emphasized in Northern areas of Finland (Kojola et al. 2018). According to endangered status of the species, great annual damages for reindeer herders and recently (in 2016) started policy of granting exceptional wolverine kill permits, Kojola et al. (2018) highlights the need for properly funded research to determine the number of wolverines more accurately.

In light of the complex aspects of wildlife and people living together, objective information on the movements, behaviour and number of animals is crucial (Cattet et al. 2018). Especially with endangered species, captures and collaring can give very useful data for conservational aspects: for example, Suutarinen and Kojola (2017) studied 130 collared wolves and showed that poaching was actually the main reason for wolf mortalities in Finland.

2.7.4 Non-invasive research methods in large carnivore research in Finland

There are non-invasive methods needing no physical handling of the animal, for example the wildlife triangle scheme in which a 12 km long triangular area is checked, and tracks, carcasses, feces and animal sightings are observed (Kojola et al. 2019). Sightings of volunteers, carnivore death statistics from officials, DNA material from feces and hair and other field research is used for large carnivore studies and population estimations (Heikkinen et al. 2018).

2.7.5 Invasive research methods in large carnivore research in Finland

Besides non-invasive methods wildlife captures have an important role in research: non-invasive methods cannot give as accurate information about daily movements of an animal as tracking device, and many samples collected in captures are valuable in conservation-associated studies (Cattet et al. 2018).

Capturing and collaring wild animals with tracking devices are used as a method to study their moving patterns (Cattet et al. 2008), which helps evaluating the territory borders movement behaviour close to habituated areas or domesticated animals and size of the population (Fahlman et al. 2008, Kojola et al. 2016, Kojola et al. 2019). Results of these studies are used as tools when planning conservation, population management and political decisions, for example granting hunt permits (Largecarnivores.fi 2019).

2.7.6 Capture methods of large carnivores used in Finnish research

According to Act on the Protection of Animals Used for Scientific or Educational Purposes (2013) in Finland a veterinarian does not have to be present in wildlife capture events: however, a designated veterinarian has to be involved to the projects for veterinary medicinal councelling. For welfare issues also other competent person instead of a veterinarian may be assigned. In Finland a veterinarian is usually not attending the capture event but other well-educated and competent specialists run the capture and handle the anaesthetics and other drugs (the designated veterinarian of wolf captures Anna Meller, personal communication 6th May 2019).

Wolverine

Wolverines are not captured in Finland at the moment (Luke 2019c). However, as Kojola et al. (2018) suggests, new research and information on wolverines in Northern Finland is needed due to the critically endangered status, inaccurate estimation of wolverine population in reindeer herding area and great losses for reindeer keepers. A genetic analyses using hair traps was launched during 2016-2018 where a food bait was set in a tree and a steel brush below it; while the animal feeds some hair will stick to the brush (Luke 2019b). The pointed shape of the head is a challenge for the collar not falling off: however, wolverines are collared in Sweden and Norway (Luke 2019c).

Bear

Bears are not collared at the moment (Figure 9) due to some problems with the collars: however, in past bears have been collared for radio tracking (Luke 2019c). The movement distance information that was gained from the collarings before, is still used for evaluating the bear population size by bear sightings combined with the movement distance estimations (Luke 2019a). The bears were often captured from carcasses, and tracking information was used for evaluating the activity, the size of the territories and differences in movement patterns between the sexes (Luke 2019c).

Wolf

In Finland a number of wolves have been radio collared during past decades: according to Kojola et al. (2014) in total 125 wolves were collared during 1998-2011 with very high frequency (VHF) and global positioning system (GPS) transmitter devices. The capture seasons were during February-April (Kojola et al. 2006). The capture team drove next to the escaping wolves with a snowmobile, and the animals were caught from the neck-area using a manheld pole which had a noose in it's end (Kojola et al. 2006). Captures during 2003-2012 were done by either darting from helicopter or chasing with snowmobile (Kojola et al. 2016).

Caught wolves were put in wooden boxes for half an hour, after which they were injected with medetomidine and ketamine at dose ratio of 1:20 (Kojola et al. 2006). Medetomidine-ketamine has also been used for immobilizing wolves in Scandinavia (Arnemo et al. 2006). However, the earlier method of using medetomidine-ketamine resulted in significantly higher mortality rates (6.9%), associated with hyperthermia and shock during anaesthesia, compared to tiletamine-zolazepam (2.2%) (Arnemo et al. 2006).

Anaesthesia protocol has recently changed also in Finland to a combination of tiletamine-zolazepam (pers. comm. with Anna Meller 2019). Immobilizing wolves by a dart from a helicopter with tiletamine-zolazepam is the recommended protocol in recent publication concerning biomedical protocols of Nordic large carnivores (Arnemo & Evans 2017). In case of unsatisfying immobilization 1 mg of medetomidine intramuscularly is suggested by Arnemo & Evans (2017); this is also used in Finland in sudden recoveries (pers. comm. with Anna Meller 2019).

During anaesthesia wolves were collared and ear-tagged (Kojola et al. 2006). Sex and age-estimate were determined, teeth checked and hair samples taken for genotypic data analyses (Kojola et al. 2006). Atipamezole, an alpha-2 antagonist, was given after the capture procedure to reverse the anaesthesia before the animal was released (Kojola et al. 2006).

Besides thermometer, no specific monitoring devices are described to have been used for anaesthesia depth monitoring in the articles used for this review. Furthermore, no additional oxygen is not used in wolf captures in Finland (pers. comm. with Anna Meller 2019).

Lynx

Lynx are collared in Finland for studying their seasonal and daily movement, size of the territories, movement close t the habitated areas, reproduction and dispersion to new areas (Luke 2019c). The lynx are either caught to live traps or captured using hunting dogs that drive the lynx up to the tree where they are darted from (Luke 2019c). Some lynx are caught from the hunters' live traps that are set for small carnivores, such as raccoon dogs or foxes, and they are immobilized by medetomidine-ketamine mixture delivered by blowpipe (pers. comm. with Anna Meller 2019). Immobilized lynx are marked and collared, except the young animals weighing under 10 kg that are only marked (Luke 2019c).

3 DISCUSSION

A lot of research about wildlife captures has been published and some comprehensive textbooks are available. In this literature review, concentrated on a broad overview on multifaceted factors of a succesfull wildlife capture and the reasons for doing captures, three focuses seemed to be the main aims for doing the wildlife captures in studies that were used for this review:

1) Gaining more information about capture methods themselves, such as comparing different methods, evaluating capture-related risks or experimenting drug combinations (Barsan et al. 1989, Jedrzejewski & Kamler 2004, Arnemo et al. 2006, Cattet et al. 2008, Buss et al. 2016, Adam et al. 2018). Today safe anaesthesia (and immobilization) is not defined only by animal surviving alive (Osofsky & Hirsch 2000, Fahlman 2008). Developing safe and smooth anaesthesia and immobilization methods and protocols require experimenting, monitoring and evaluating them systemically. Animal welfare and ethical issues are nowadays considered more than a few decades ago, since more information about them and more humane pharmacological options are available now compared to the past (Osofsky & Hirsch 2000).

2) Translocations, which have especially either conservational or commercial purposes (Osofsky & Hirsch 2000, Kock et al. 2010, Lekolool 2012).

3) Other conservation purposes (not necessarily including the translocation of the animal) or getting some other specific information about the animals, such as taking blood samples for disease monitoring or radio collaring the animals for movement tracking (Kolbe et al. 2003, Kojola et al. 2009, Macbeth et al. 2010, Worldbank 2010, Kojola et al. 2016, Miller et al. 2019). For example, increase of

human population, urbanization and habitat fragmentation has lead to human-wildlife conflicts and endangerement of numerous wildlife species on many sides of the world. Information gathered from wildlife captures and translocations of animals or animal groups is an important part of solving these problems. Often one or more focuses are combined in one capture, and as much information as possible is desired to be gathered from the capture event.

In this review also a short insight to large carnivore captures in Finland was made. No publications specifically on wildlife immobilization or capture methods were found related to the topic. Most of the studies were related to population management, conservation and human-wildlife conflict issues, and anaesthetic methods were mentioned shortly aside. Furthermore, a majority of recent large carnivore publications made in Finland seemed to be focused on wolf, propably due to the heated public discussion and political interest about the species (Hiedanpää & Pellikka 2017).

In Finnish large carnivore captures immobilization and anaesthetic drug protocols used seemed to be in line with the Nordic large carnivore immobilization recommendations of Arnemo & Evans (2017). Thorough anaesthetic monitoring is not done in the captures (pers. comm. with Anna Meller 2019). Measurement and weighing of the animals are done, and additional oxygen is not used in wolf captures. As Fahlman et al. (2014) mention hypoxemia is an anticipated anaesthesia complication during all wildlife anaesthesia. Taking additional oxygen as part of the immobilization procedure in Finnish captures has been discussed and it is in future plans, which will propably be a good improvement for the anaesthesia protocol: for example, intranasal administration throughout anaesthesia proved to be simple and practical method for preventing hypoxia in bears, that quickly became hypoxemic when oxygen supplementation was discontinued (Fahlman et al. 2014). Other practical and cost-effective monitoring methods for improved anaesthesia safety to be considered could be the systemical use of pulse oxymeter and thermometer.

At the moment, a huge trend in wildlife related studies, and the bigger picture behind wildlife captures, is the aspect of One Health and emerging infectious diseases (Worldbank 2010). Tight connection between humans, wildlife and domestic animals has created a need for holistic, interdisciplinary approach to understand health-related issues (Worldbank 2010). Tragic interspecies-transmitted disease epidemias, such as seen with Ebola virus, highly pathogenic avian influenza and Nipah virus, make sure that profound wildlife research is continuously needed both now and in the future, too (Worldbank 2010).

As Miller et al. (2019) point out, human and veterinary medicine, ecology, epidemiology and other branches of science are crucial together for understanding and managing disease and health relating issues of all living organisms. Dickman (2010) also emphasizes the importance of economical, psychological, anthropological science and conflict study professionals regarding to conservation and human-wildlife conflict. Furthermore, Hing et al. (2016) propose that a greater attention should be paid also for better understanding of the stress-disease synergism to see the affects of antropomorphic stressors to disease dynamics. The wildlife capture originated information, such as samples and radio collar related movement data, are significant factors of the wildlife part of One Health approach.

4 CONCLUSIONS

Figure 10. *Since poaching for the rhino horn is a large problem in South Africa (Taylor et al. 2015) rhinos are often captured and dehorned for making them less interesting targets for the poachers. In this photo a white rhino (Ceratotherium simum) was captured for this conservation issue: the animal was immobilized using etorphine-butorphanol-azaperone and the horn was sawed away. Photo © Henna Kaarakainen*

As explained, wildlife captures play a crucial part in protecting and understanding overall health and well-being of all human and non-human animals, by allowing us to get information about the pathogens that we commonly share or that are otherwise affected by the complex human-wildlife-livestock (-environment) interface. Besides being one piece of the whole puzzle of interspecies pathogens, wildlife, nature and the knowledge about them and world surrounding us can be seen as an essential intrinsic value itself. In captures such information that is not available by non-invasive methods can be gathered about the animals and ecosystems. Furthermore, translocations are a crucial part of both conservation projects and purposes in endangered species (Figure 10) and commercial wildlife industry. Since wildlife captures have a large role in such multiple purposes, it is essential to consider and research all the aspects that form a safe and well-managed wildlife capture.

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"If we kill off the wild, then we are killing a part of our souls."

- Jane Goodall –

"I believe alien life is quite common in the universe,
although intelligent life is less so.
Some say it has yet to appear on planet Earth."

- Stephen Hawking –

"Snakes. Why'd it have to be snakes?"

- Indiana Jones –